



Interplanetary Network Directorate

*Final*



# *Process Control Network Operations*

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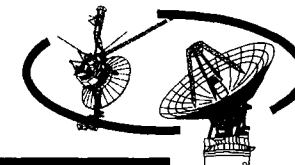
## **History of DSN Operational Metrics**

- **NASA's Deep Space Network comprises three deep space communications complexes (DSCC) and a Network Operations Control Center located at the Laboratory in Pasadena, California.**
- **The DSMS Operations Program Office, within the Interplanetary Network Directorate at the Jet Propulsion Laboratory, is programmatically responsible for operating and maintaining the DSN for NASA.**
- **Prior to 1997, monthly performance parameters were provided to NASA Headquarters.**
- **Availability for three major deliverables to flight projects was derived from the discrepancy reporting (DR) system and scheduling information from archived Network schedules.**
- **The scheduling history provides the time that antennas and data systems were committed to provide service to DSN customers.**
- **The DR system is used to record the time when systems failed and were not available to provide scheduled service.**



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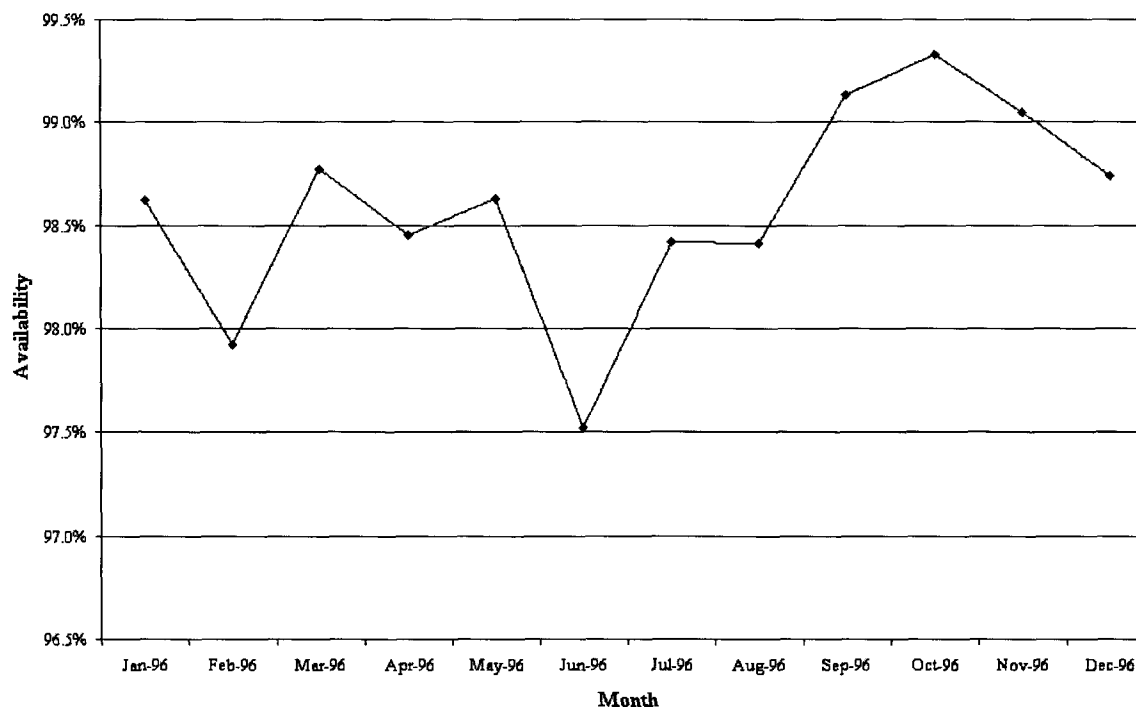
# History of DSN Operational Metrics



➤ Availability is defined as  $Availability = \frac{T_s - T_l}{T_s} \times 100$

➤ Because a pictorial representation of the availability was desired, a run chart was generated that showed the most recent 12 monthly performance values.

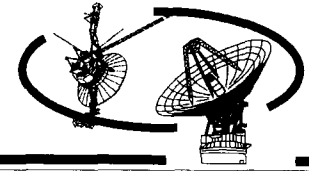
DSN Telemetry Availability





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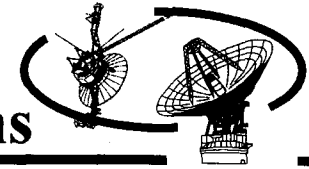
## **History of DSN Operational Metrics**



- **There Were Several Problems With The Run Chart**
  - **If a drop in performance occurred in any particular month compared to a previous month, additional analysis was done using the the DR system in an attempt to identify what causes could have contributed to the perceived degradation, and to prepare for questions about those causes.**
  - **What constituted a significant drop in performance was totally subjective.**
  - **Because the performance value was an aggregate across all subnetworks and causes, there is no value in using the chart for process improvement.**
  - **There is no way of determining what the level of common cause variation is in the monthly values.**
  - **There is no way of determining the process capability.**



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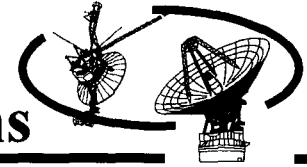


## **The Introduction of SPC Into DSN Operations**

- **Operations decided to implement a system to monitor performance and to use for evaluating process improvement efforts.**
  - **The system had to be cost effective.**
  - **The existing data gathering and reporting processes would have to be taken advantage of.**
- **Several commercial software applications were investigated.**
- **Quality Analyst from Northwest Analytical was chosen.**
  - **Most types of Shewhart charts are generated.**
  - **Additional statistical tools are provided; e.g. capability charts.**
  - **Data from the DR system and scheduling history was easily imported to the software.**
  - **Western Electric zone rules are automatically tracked.**
- **Individuals and range (XmR) charts were chosen as the format.**



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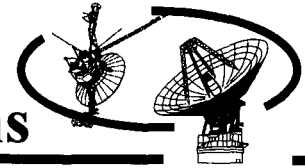


## **The Introduction of SPC Into DSN Operations**

- **Donald Wheeler recommends XmR charts.**
  - **XmR charts are appropriate for population data.**
  - **XmR charts can be used for short runs, although the limits will be somewhat soft.**
  - **They are statistically valid for several probability distributions.**
- **Process capability calculations are easily done with XmR charts, since the populations standard deviation can be determined directly.**
- **The DSN databases provide population data for scheduling and for discrepancies.**
  - **Allowed an historical baseline of performance.**



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## **The Introduction of SPC Into DSN Operations**

- **The telemetry example (next page):**
  - **The mean performance (cl) is 99.28%.**
  - **The upper control limit is (ucl) 99.91%.**
  - **The lower control limit is (lcl) 98.65%.**
  - **The lower specification limit (LSL) is 98%. This is the engineering specification for the functional availability of a single string of equipment required to capture and deliver telemetry to a customer.**
  - **The rule violations are denoted by pound signs outside  $3\sigma$  limits, and asterisks within  $3\sigma$  limits.**
- **Although the XmR charts for overall Network availability provide a general, high-level indication of performance, they cannot be used for process improvement.**
  - **Noise is additive and can mask poor performance with a particular subnetwork, antenna, system, or process.**



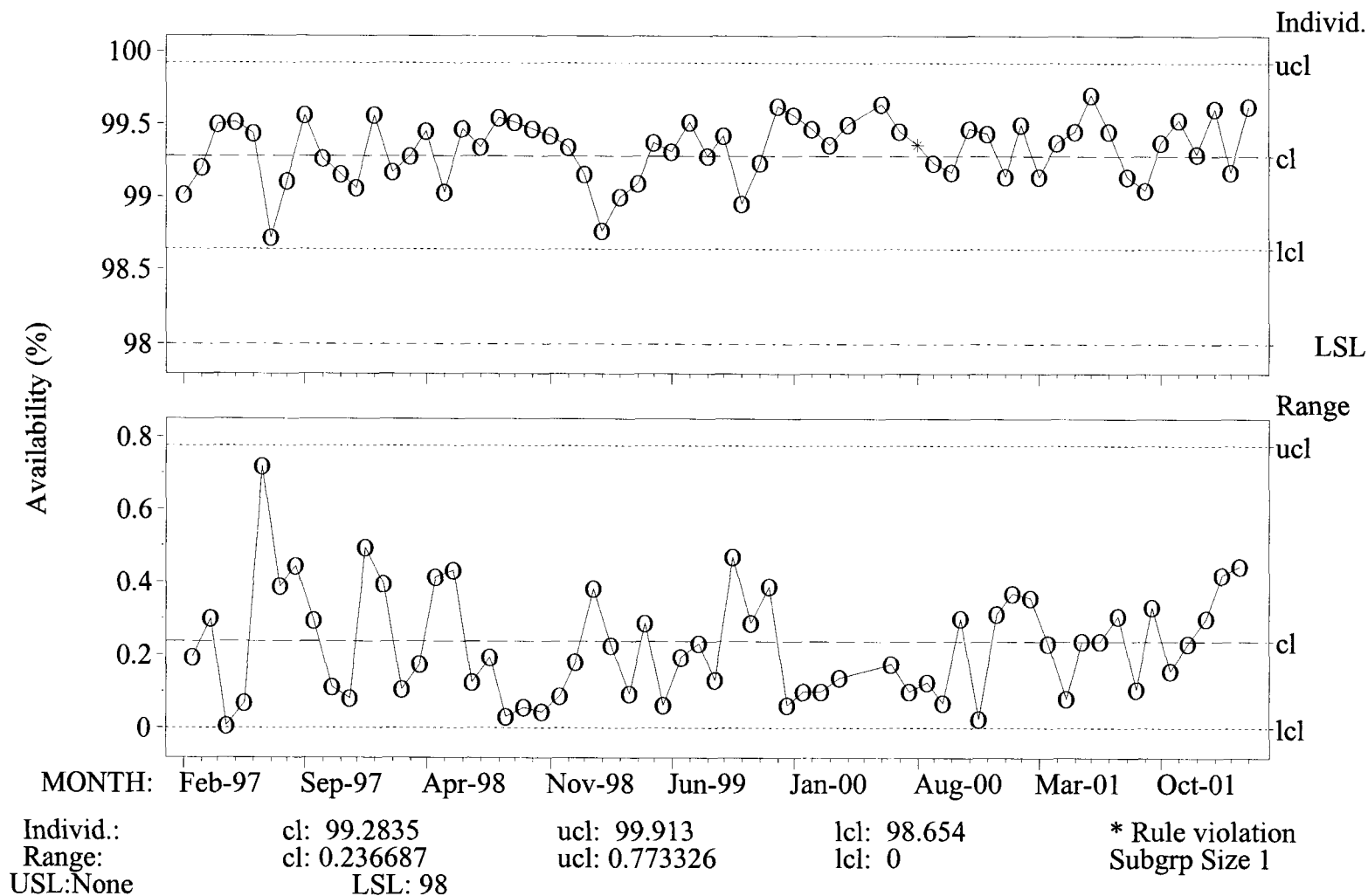
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## Deep Space Network Operations



# The Introduction of SPC Into DSN Operations

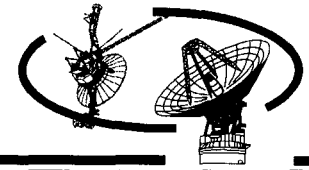
4/30/02 File: NETTLM.DAT  
Deep Space Network  
Telemetry Functional Availability







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## **How SPC Is Used for Process Improvement**

- **SPC was applied to the process used to generate support products for the Network.**
  - **Support products include pointing predictions for the antennas, receivers, telemetry data systems, and the radio metric data assemblies.**
- **The historical performance shows that the mean performance was 11 problems per month.**
- **The upper and lower control limits were 26 and -3.**
  - **Since the lower limit is not practical it can be clamped at zero by setting the software.**



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## Deep Space Network Operations

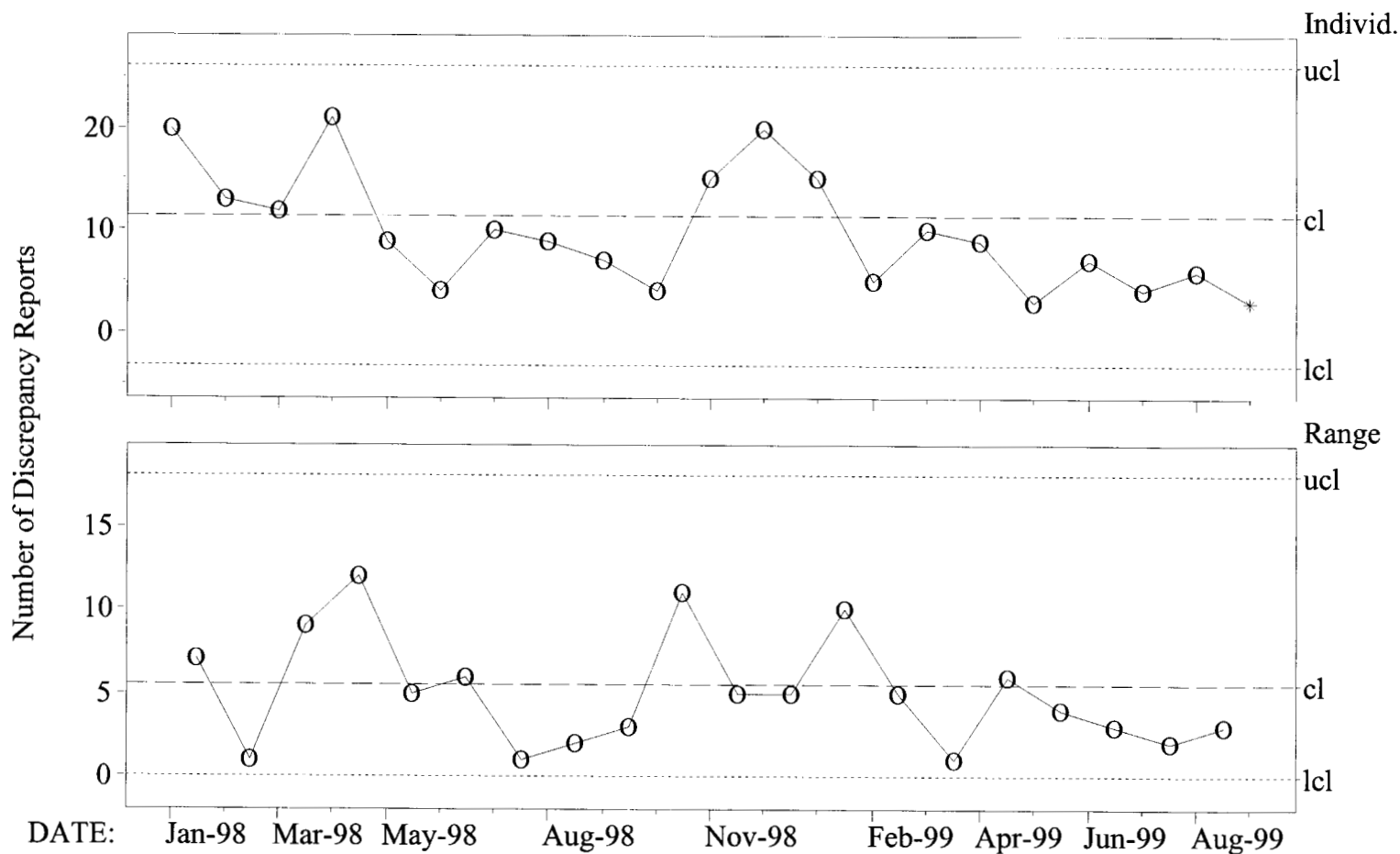


# How SPC Is Used for Process Improvement

5/1/02 File: SVE2.DAT

SVE Metrics; Quality

Support Product DRs



Individ.:

cl: 11.4375

ucl: 26.1538

lcl: -3.27881

\* Rule violation

Range:

cl: 5.53333

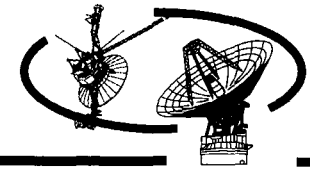
ucl: 18.079

lcl: 0

Subgrp Size 1



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## **How SPC Is Used for Process Improvement**

- **In early 1999, CSOC initiated a process improvement task to improve the problems experienced with the support product generation process.**
  - **Personnel were cross trained to provide depth in capability.**
  - **Work instructions were improved.**
- **The improvement in performance was indicated by the control chart by the asterisk for the September value.**
  - **The rule violation was 8 values on one side of the central line. This indicated that the actual improvement had begun in May, shortly after the new work instructions had been put in place and the training was completed.**
- **The chart was then modified to use the 8 violation data points to calculate the new mean.**
  - **As indicated in the revised chart, the new mean was approximately 4 DRs per month.**
  - **Variation has also decreased significantly.**
  - **There had been better than a 100% improvement in the process.**
  - **This represents the new baseline of performance that is being used.**



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## Deep Space Network Operations

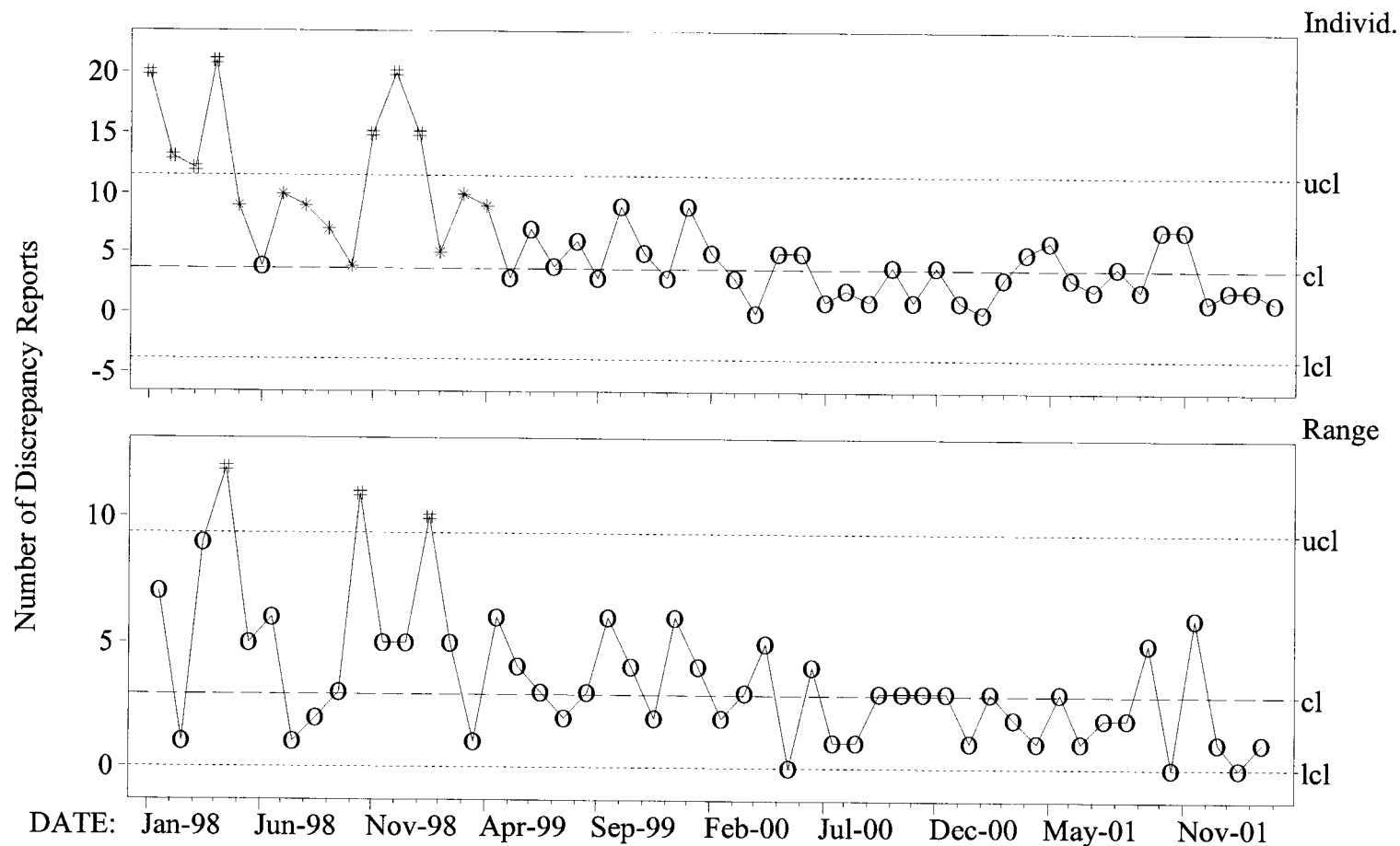


# How SPC Is Used for Process Improvement

4/30/02 File: SVE2.DAT

SVE Metrics; Quality

Support Product DRs



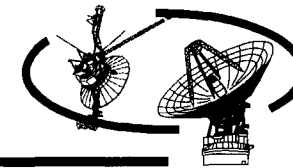
Individ.:  
Range:

cl: 3.8  
cl: 2.875

ucl: 11.4463  
ucl: 9.39345

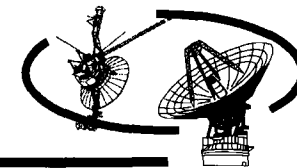
lcl: -3.84628  
lcl: 0

\* Rule violation  
Subgrp Size 1



## **New Uses of SPC**

- **DSMS Operations is working with the DSMS Engineering Office to evaluate the performance of new or upgraded systems.**
  - **In the year 2000, DSMS made a decided to redesign the VLBI system for independently validating Doppler and ranging data used for navigation for the Mars missions.**
  - **The older architecture was almost 20 years old and contained many analog subassemblies.**
  - **The aging equipment and the inherent design resulted in less than specified functional availability, and this resulted in less than the required data return.**
  - **The system was also required periodic alignment.**
- **As shown in the historical chart, the mean (cl) functional availability was 96%.**
- **The upper and lower specifications (ucl and lcl) are 103% and 88% respectively.**
  - **The ucl is not practical and can be clamped by software.**



## New Uses of SPC

- The system was incapable of consistently (  $c$  ) meeting the functional availability specification (LSL) of 92%.
- The process capability index ( or  $C_{pk}$  ) is calculated as  $C_{pk} = \frac{DNS}{3\sigma}$
- Where DNS is the distance to the nearest specification, and  $\sigma$  is the standard deviation calculated from the chart.

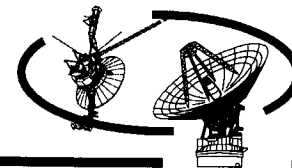
$$C_{pk} = \frac{DNS}{3\sigma} = \frac{95.7 - 92}{95.7 - 88.3} = \frac{3.7}{7.4} = 0.5$$

- This confirms what we already knew intuitively from the chart; the process is not at all capable!
- For a process to be considered good, the capability index should be equal to or greater than 1.3.



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## Deep Space Network Operations

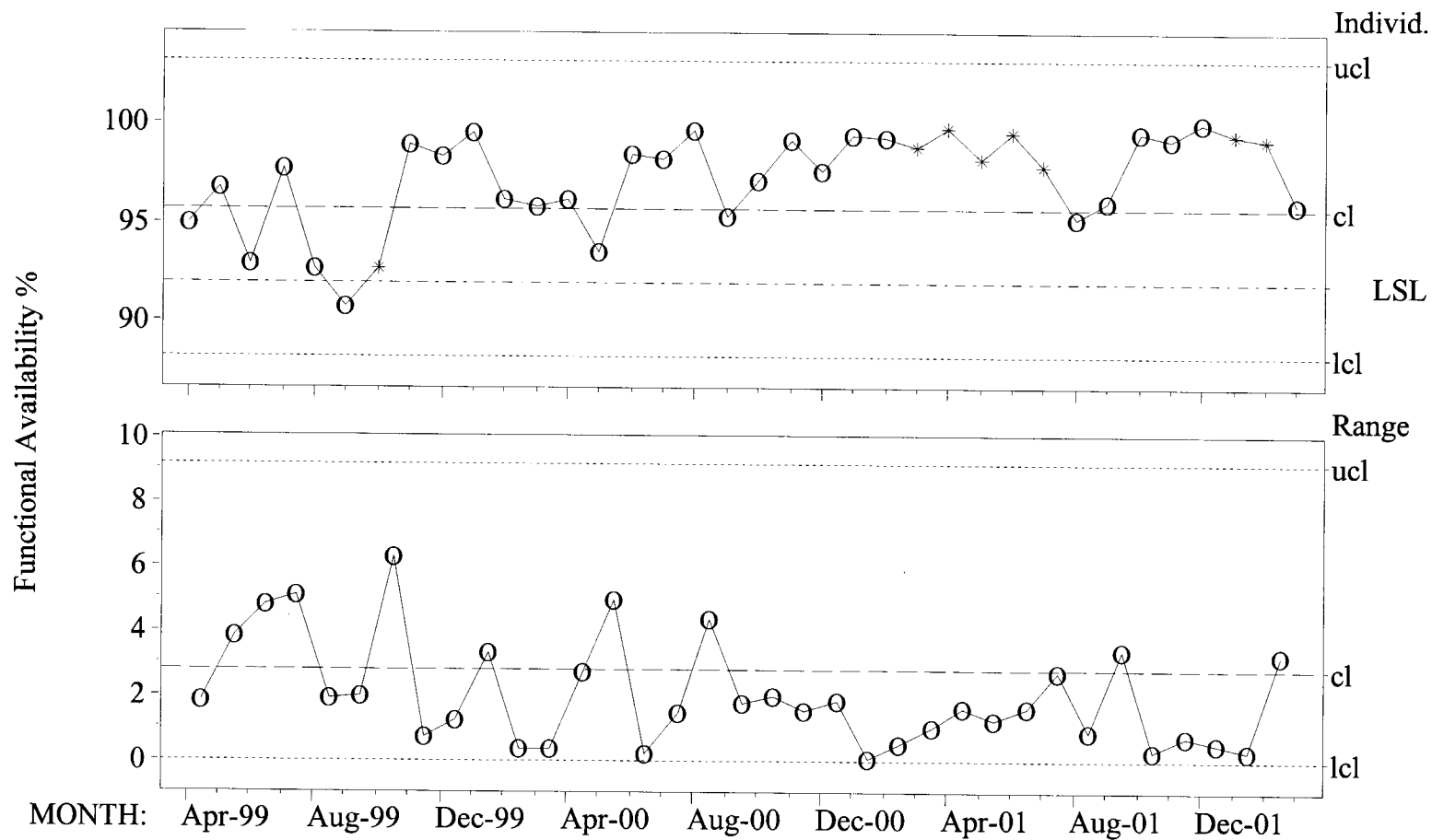


# New Uses of SPC

4/30/02 File: NETVLBI.DAT

DSN VLBI Availability

VLBI Functional Availability



Individ.:  
Range:  
USL:None

cl: 95.7006  
cl: 2.80193  
LSL: 92

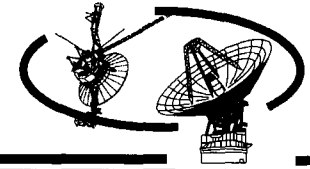
ucl: 103.153  
ucl: 9.15471

lcl: 88.2487  
lcl: 0

\* Rule violation  
Subgrp Size 1



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## **New Uses of SPC**

- **The revised chart, using the performance data from the new system, indicates a significant improvement in the system.**
  - **The new mean (cl) is 98%.**
  - **The variation has decreased from 7% to 4%.**
  - **The lower control limit (lcl) now exceeds the required functional availability specification (LSL).**
  - **The capability of the system is now...**

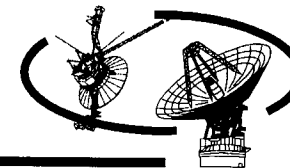
$$C_{pk} = \frac{DNS}{3\sigma} = \frac{98.3 - 92}{98.3 - 94.2} = \frac{6.3}{4.1} = 1.54$$





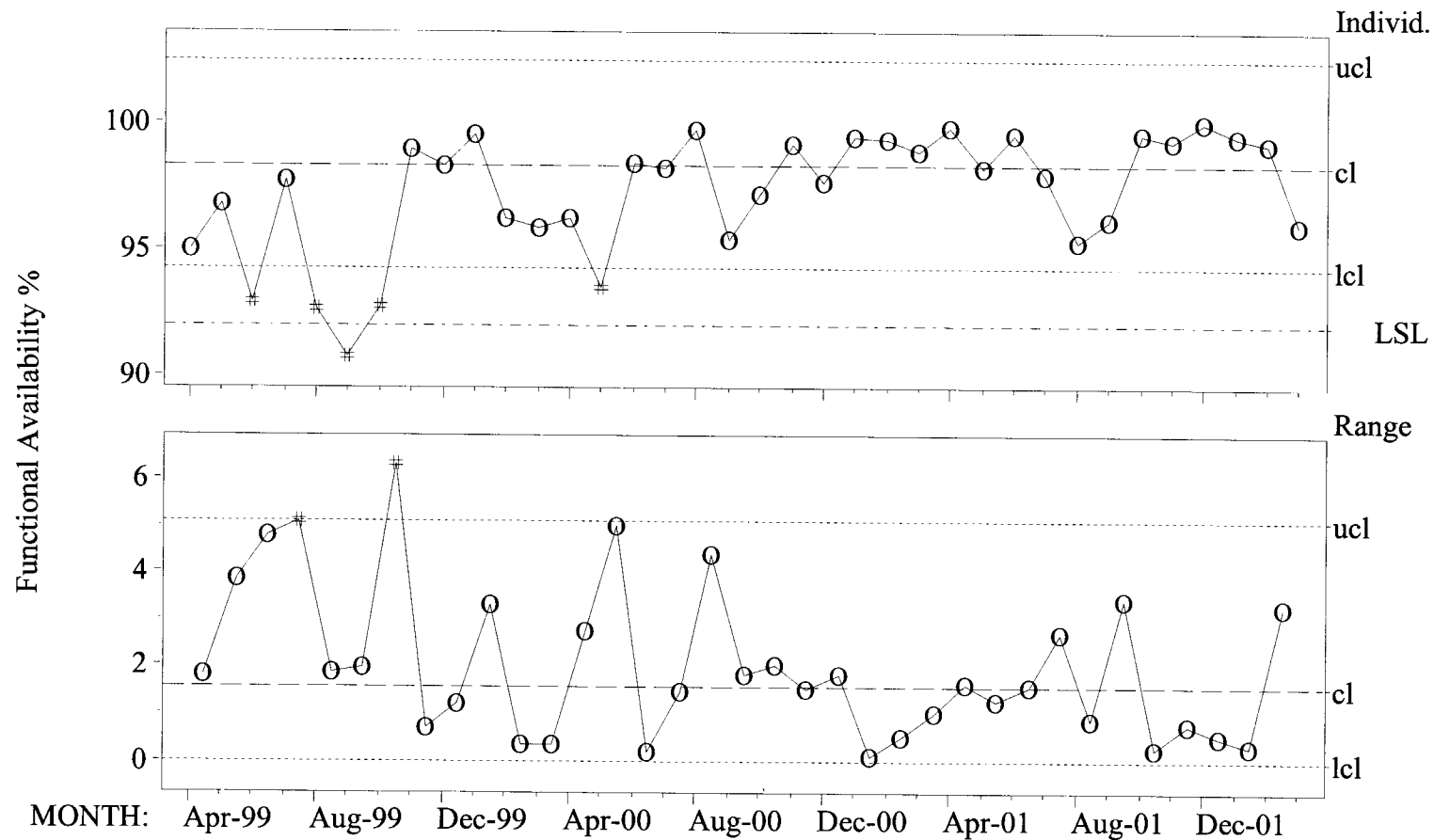
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## Deep Space Network Operations



# New Uses of SPC

4/30/02 File: NETVLBI.DAT  
DSN VLBI Availability  
VLBI Functional Availability

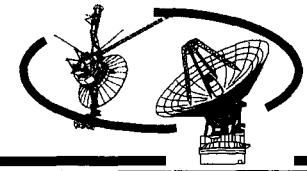


Individ.:	cl: 98.341	ucl: 102.457	lcl: 94.2246	* Rule violation Subgrp Size 1
Range:	cl: 1.54775	ucl: 5.05694	lcl: 0	
USL:None	LSL: 92			



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## Summary



- **SPC has proven to be a valuable tool in the DSN Operations for evaluating overall performance, improving operations processes in its service environment, and for validating performance of new or upgraded systems.**
- **If the appropriate performance data architecture is already in place, SPC can be implemented for a modest cost.**
- **SPC provides the signals for making objective decisions on expending resources for process improvement in both operations and engineering.**
- **DSN Operations continues to explore new uses of SPC.**